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Book of Abstracts
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Kellie Ann Beall, Editor

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In-situ Burning of Water-in-Oil Emulsions : Model Results and Comparison with Data

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Introduction

In-situ burning of oil or water-in-oil (w/o) emulsion supported on top of a water-base, such as the ocean, is a complex process, and it involves several interdependent and complex physicochemical processes which are not yet fully understood. The technique of in-situ oil spill combustion has been tried in practice and investigated by researchers sporadically over the past thirty years. The focus of this report is on the burning of water-in-oil emulsions with an emphasis on computation of timeline for the important events in the process, such as the ignition delay, complete consumption of the emulsion layer, burnout period, residue left, and efficiency of removal.

The Model

The combustion process starts with heat transfer from a source, such as an igniter or adjacent fire, to the emulsion layer. For the modeling purpose, the overall burning process is divided into three regimes as follows.

1. *Initial Regime* ($t = 0$ to t_1) : The emulsion layer is heated with a constant heat flux source and the top surface reaches the emulsion-breaking temperature.

2. *Intermediate Regime*: ($t = t_1$ to t_2): Continued input of heat provides the energy required for emulsion breaking which causes the first appearance of oil on top of the emulsion. Thus, there are three layers in this regime, oil, emulsion and water. Figure 1 shows a schematic at this stage. The temperature of the oil layer increases while the oil-emulsion interface temperature remains constant at the emulsion breaking temperature. When the oil surface temperature reaches vaporization temperature, the intermediate regime ends.

3. *Final Regime*: ($t = t_2$ to t_3): The vaporized oil burns because of the presence of the fire, energy is released by oil combustion, and a part of it is fed back to the oil. The burning process continues until the emulsion layer completely depletes, oil layer continues to burn, and finally extinction occurs because the loss of heat to the water becomes greater than the heat feedback to the oil surface.

The mathematical model is one-dimensional. Full set of governing equations and additional details may be found in a paper by Walavalkar and Kulkarni, 1997.

Results and Comparisons

All numerical results were obtained assuming emulsions were prepared from SAE30 motor oil because of availability of properties for that oil. Figure 2 shows comparison of ignition delay values with those obtained by Putorti et al., (1994). The average burning rate is compared with the data of Buist et al. (1995) in Fig 3. A comparison of data by Buist et al. (1995) for ANS crude oil emulsions and by Guennette et al.(1994) for the burn efficiency is shown in Fig. 4. Though most of these experiments were conducted with emulsions of other oils the experimental values and model results compare very well. The present model illustrates the parametric effects of external heat flux, emulsion layer thickness and emulsion composition on such important quantities as the ignition delay, total burnout period, efficiency of removal, residual layer thickness, and transient and steady burning rates (not all results are presented here). There is a strong need for a systematic experimental study to verify applicability of the model. Also, accurate property data for crude oils and their emulsions, along with a realistic assessment of weathering and other conditions, are needed for applying the model to practical situations. Once validated, the present model can give reasonable idea as to whether an emulsion layer under given conditions can burn, and if so, how long will it take and what will be its effectiveness.

Part of this research and a major experimental program to study burning of w/o emulsions is currently funded at Penn State under a recent NIST grant no. NANB0036.

References

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3. Putorti, A. D., Jr. and D. Evans, "Ignition of Weathered and Emulsified Oils," Proceedings of *the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, 1:657-667, 1994.

4. Walavalkar, A. and Kulkarni, A. K., 1997. A Mathematical Model for In-Situ Burning of Water-in-Oil Emulsions, Proceedings of the *Twentieth Arctic and Marine Oilspill Program Technical Seminar*, pp 809-821, Vancouver, Canada.

Fig. 1. Model Schematic

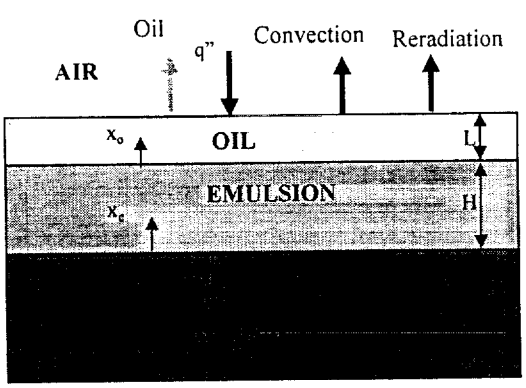


Fig. 2. Ignition Delay Vs Emulsion Water Content

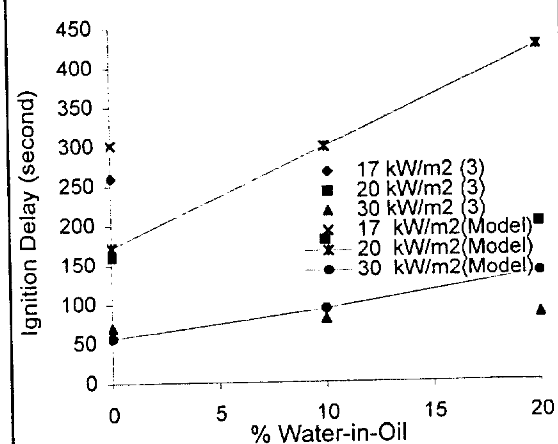


Fig. 3. Burn Rate Vs % Emulsion Water Content

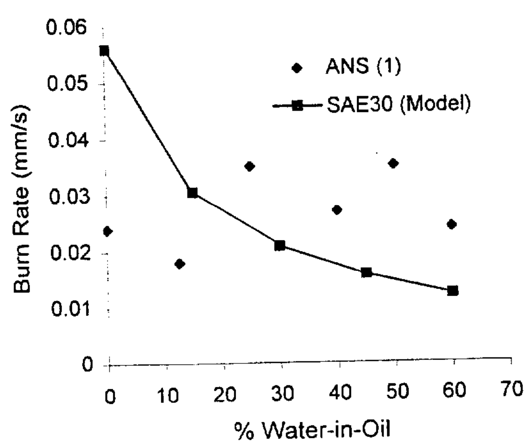
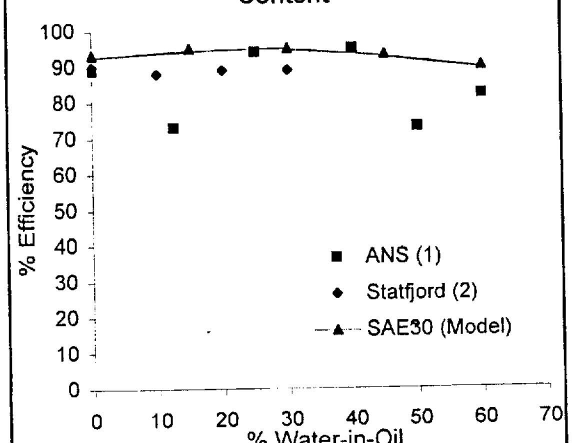


Fig. 4. Efficiency Vs Emulsion Water Content



(Reference numbers in figures correspond to the citations above.)